

The Pending Claims

1. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container; wherein the substrate holder comprises:

i) a vacuum chuck having a substrate support surface; and

ii) an elastomer ring disposed around the substrate support surface, the elastomer ring contacting a peripheral portion of the substrate;

b) a cathode electrically contacting the substrate plating surface;

c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface; and

d) an anode electrically connected to the electrolyte.

2. (Issued) The apparatus of claim 1 wherein the substrate holder further comprises:

iii) one or more bubble release ports having one or more openings adjacent an edge of the substrate supporting surface.

3. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container; wherein the substrate holder comprises:

i) a vacuum chuck having a substrate support surface; and

ii) a gas bladder disposed around the substrate support surface, the gas bladder adapted to contact a peripheral portion of the substrate;

b) a cathode electrically contacting the substrate plating surface;

c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface; and

d) an anode electrically connected to the electrolyte.

4. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;

b) a cathode electrically contacting the substrate plating surface, wherein the cathode comprises a cathode contact member disposed at a peripheral portion of the substrate plating surface, the cathode contact member having a contact surface adapted to electrically contact the substrate surface, wherein the cathode contact member comprises a radial array of contact pins and a resistor connected in series with each contact pin;

c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface; and

d) an anode electrically connected to the electrolyte.

5. (Issued) The apparatus of claim 4 wherein the cathode further comprises a sensor connected across each resistor to monitor the current flowing through the resistor.

6. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;

b) a cathode electrically contacting the substrate plating surface;

c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface, wherein the electrolyte outlet is defined by a gap between a first surface on the substrate holder extending radially outward from the substrate plating surface and a surface of the electrolyte container; and

d) an anode electrically connected to the electrolyte.

7. (Issued) The apparatus of claim 6 wherein the gap has a gap width between about 1 mm and about 30 mm.
8. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:
- a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;
 - b) a cathode electrically contacting the substrate plating surface;
 - c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;
 - d) an anode electrically connected to the electrolyte; and
 - e) a control electrode disposed in electrical contact with the electrolyte, the control electrode adapted to provide an adjustable electrical power.
9. (Issued) The apparatus of claim 8 wherein the control electrode is disposed outside of the electrolyte container and in electrical contact with an outflowing electrolyte in the electrolyte outlet.
10. (Issued) The apparatus of claim 8 wherein the control electrode comprises an array of electrode segments.
11. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:
- a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;
 - b) a cathode electrically contacting the substrate plating surface;
 - c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;
 - d) an anode electrically connected to the electrolyte; and

e) a vibrator attached to the substrate holder, the vibrator transferring a vibration to the substrate holder.

12. (Issued) The apparatus of claim 11 wherein the vibrator is adapted to vibrate the substrate holder in one or more directions.

13. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;

b) a cathode electrically contacting the substrate plating surface;

c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;

d) an anode electrically connected to the electrolyte; and

e) a sleeve insert disposed at a top portion of the electrolyte container, the sleeve insert defining the opening of the electrolyte container.

14. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;

b) a cathode electrically contacting the substrate plating surface;

c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;

d) an anode electrically connected to the electrolyte; and

e) a flow adjuster wedge disposed at a top portion within the electrolyte container.

15. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

- a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container,
- b) a cathode electrically contacting the substrate plating surface;
- c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface,
- d) an anode electrically connected to the electrolyte; and
- e) a gas knife to supply a gas flow across the wafer plating surface to remove residual electrolyte.

16. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

- a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;
- b) a cathode electrically contacting the substrate plating surface;
- c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;
- d) an anode electrically connected to the electrolyte; and
- e) a wafer catcher disposed at a top portion within the electrolyte container.

17. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

- a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;
- b) a cathode electrically contacting the substrate plating surface;
- c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;
- d) an anode electrically connected to the electrolyte; and
- e) a reference electrode adapted to monitor the cathode and the anode.

18. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

- a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;
- b) a cathode electrically contacting the substrate plating surface;
- c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;
- d) an anode electrically connected to the electrolyte; and
- e) a rinsing solution supply selectively connected to the electrolyte inlet.

19. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate having a substrate plating surface, comprising:

- a) a substrate holder adapted to hold the substrate in a position wherein the substrate plating surface is exposed to an electrolyte in an electrolyte container;
- b) a cathode electrically contacting the substrate plating surface;
- c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive the substrate plating surface;
- d) an anode electrically connected to the electrolyte; and
- e) gas bubble diverting vanes disposed within the electrolyte container to divert gas bubbles toward an electrolyte container sidewall.

20. (Issued) A method for electrochemical deposition of a metal onto a substrate, comprising:

- a) providing an electrochemical deposition cell comprising:
 - 1) a substrate holder;
 - 2) a cathode electrically contacting a substrate plating surface;
 - 3) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive a substrate plating surface; and
 - 4) an anode electrically connected to an electrolyte;
- b) applying electrical power to the cathode and the anode; and
- c) flowing an electrolyte to contact the substrate plating surface, wherein the electrolyte flows between about 0.25 gallons per minute (gpm) to about 15 gpm.

21. (Issued) A method for electrochemical deposition of a metal onto a substrate, comprising:

- a) providing an electrochemical deposition cell comprising:
 - 1) a substrate holder;
 - 2) a cathode electrically contacting a substrate plating surface;
 - 3) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive a substrate plating surface; and
 - 4) an anode electrically connected to an electrolyte;
- b) applying electrical power to the cathode and the anode; and
- c) flowing an electrolyte to contact the substrate plating surface;

wherein the step of applying an electrical power to the cathode and the anode comprises:

- 1) applying a cathodic current density between about 5 mA/cm² and about 40 mA/cm² for about 1 second to about 240 seconds.

22. (Issued) The method of claim 21 wherein the step of applying an electrical power to the cathode and the anode further comprises:

- 2) applying a dissolution reverse current between about 5 mA/cm² and about 80 mA/cm² for about 0.1 seconds to about 100 seconds.

23. (Issued) A method for electrochemical deposition of a metal onto a substrate, comprising:

- a) providing an electrochemical deposition cell comprising:
 - 1) a substrate holder;
 - 2) a cathode electrically contacting a substrate plating surface;
 - 3) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive a substrate plating surface; and
 - 4) an anode electrically connected to an electrolyte;
- b) applying electrical power to the cathode and the anode; and
- c) flowing an electrolyte to contact the substrate plating surface;

wherein the step of applying an electrical power to the cathode and the anode comprises:

- 1) applying a cathodic current density between about 5 mA/cm.² and about 40 mA/cm.² for about 1 second to about 240 seconds;
- 2) applying a dissolution reverse current between about 5 mA/cm.² and about 80 mA/cm.² for about 0.1 seconds to about 100 seconds;
- 3) applying a cathodic current density between about 5 mA/cm.² and about 40 mA/cm.² for about 1 seconds to about 240 seconds; and
- 4) repeating step 2 and step 3.

24. (Issued) A method for electrochemical deposition of a metal onto a substrate, comprising:

- a) providing an electrochemical deposition cell comprising:
 - 1) a substrate holder;
 - 2) a cathode electrically contacting a substrate plating surface;
 - 3) an electrolyte container having an electrolyte inlet an electrolyte outlet and an opening adapted to receive a substrate plating surface; and
 - 4) an anode electrically connected to an electrolyte;
- b) applying electrical power to the cathode and the anode;
- c) flowing an electrolyte to contact the substrate plating surface;
- d) providing a control electrode in electrical contact with an electrolyte of an electrochemical deposition cell; and
- e) adjusting the electrical power provided by the control electrode during deposition.

25. (Issued) The method of claim 24 wherein the electrical power provided by the control electrode is adjusted synchronously with a deposition/dissolution cycle of an electrochemical deposition process.

26. (Issued) A method for electrochemical deposition of a metal onto a substrate, comprising:

- a) providing an electrochemical deposition cell comprising:
 - 1) a substrate holder;
 - 2) a cathode electrically contacting a substrate plating surface;
 - 3) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive a substrate plating surface; and
 - 4) an anode electrically connected to an electrolyte;
- b) applying electrical power to the cathode and the anode;
- c) flowing an electrolyte to contact the substrate plating surface; and
- d) vibrating a component of the electrochemical deposition cell in one or more directions.

27. (Issued) A method for electrochemical deposition of a metal onto a substrate, comprising:

- a) providing an electrochemical deposition cell comprising:
 - 1) a substrate holder;
 - 2) a cathode electrically contacting a substrate plating surface;
 - 3) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive a substrate plating surface; and
 - 4) an anode electrically connected to an electrolyte;
- b) applying electrical power to the cathode and the anode;
- c) flowing an electrolyte to contact the substrate plating surface; and
- d) vibrating a component of the electrochemical deposition cell at a vibrational frequency between about 10 Hz and about 20,000 Hz and a vibrational amplitude between about 0.5 micron and about 100,000 micron.

28. (Issued) A method for electrochemical deposition of a metal onto a substrate, comprising:

- a) providing an electrochemical deposition cell comprising:
 - 1) a substrate holder;
 - 2) a cathode electrically contacting a substrate plating surface;

3) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive a substrate plating surface; and

4) an anode electrically connected to an electrolyte;

b) applying electrical power to the cathode and the anode;

c) flowing an electrolyte to contact the substrate plating surface;

d) rotating the substrate holder about a central axis through the substrate.

29. (Issued) An apparatus for electrochemical deposition of a metal onto a substrate, comprising:

a) a substrate holder comprising:

i) a vacuum chuck having a substrate support surface; and

ii) an elastomer ring disposed around the substrate support surface, the elastomer ring contacting a peripheral portion of the substrate.

b) a cathode electrically contacting a substrate plating surface;

c) an electrolyte container having an electrolyte inlet, an electrolyte outlet and an opening adapted to receive a substrate plating surface, wherein the electrolyte outlet is defined by a gap between a first surface extending radially outward from the substrate plating surface and a surface of the electrolyte container;

d) an anode electrically connected to an electrolyte, the anode comprising:

i) a porous enclosure for flow of an electrolyte therethrough;

ii) a metal disposed within the enclosure; and

iii) an electrode disposed within the enclosure;

e) a control electrode in electrical contact with an electrolyte, the control electrode adapted to provide an adjustable electrical power; and

f) a vibrator attached to the substrate holder, the vibrator adapted to transfer a vibration in one or more directions to the substrate holder.

30. (Canceled)

31. (New) An apparatus for electrochemically depositing a metal onto a semiconductor substrate, comprising:

a container having a fluid inlet, a fluid outlet, and an open portion, the container being configured to contain an electrochemical plating solution therein;

a substrate holder assembly configured to electrically contact a substrate plating surface and support the plating surface in fluid communication with the electrochemical plating solution via the open portion;

an anode in fluid communication with the electrochemical plating solution; and

a porous fluid flow adjustment member positioned across the container between the anode and the open portion, wherein the porous fluid flow adjustment member comprises a ceramic member.

32.-37. (Canceled)

38. (New) An apparatus for electrochemically depositing a metal onto a semiconductor substrate, comprising:

a container having a fluid inlet, a fluid outlet, and an open portion, the container being configured to contain an electrochemical plating solution therein;

a substrate holder assembly configured to electrically contact a substrate plating surface and support the plating surface in fluid communication with the electrochemical plating solution via the open portion, wherein the substrate holder assembly comprises a cathode contact member and a backside substrate engaging member configured to urge the substrate plating surface against the cathode contact member;

an anode in fluid communication with the electrochemical plating solution; and

a porous fluid flow adjustment member positioned across the container between the anode and the open portion.

39. (New) The apparatus of claim 38, wherein the cathode contact member comprises:

an annular member; and

at least one substrate contact element positioned on the annular member.

40. (New) The apparatus of claim 39, comprising an insulative coating positioned on an outer surface of the annular member.

41. (New) The apparatus of claim 39, wherein the at least one substrate contact element comprises a continuous ring configured to electrically contact a perimeter of the plating surface.

42. (New) The apparatus of claim 39, wherein the at least one substrate contact element comprises a plurality of substrate contact pins radially positioned on the annular member to electrically contact a perimeter of the plating surface.

43. (New) The apparatus of claim 39, comprising at least one bubble release port positioned adjacent an edge of the annular member.

44. (New) The apparatus of claim 42, comprising an annular seal member positioned on the annular member radially inward of the plurality of substrate contact pins, the annular seal member being configured to sealably engage the plating surface to prevent the electrochemical plating solution from passing therebetween.

45. (New) The apparatus of claim 41, comprising an O-ring seal member positioned radially inward of the continuous ring.

46. (New) The apparatus of claim 38, wherein the backside substrate engaging member comprises an elastomer seal positioned to sealably engage a backside perimeter of the substrate.

47. (New) The apparatus of claim 38, wherein the backside substrate engaging member comprises an inflatable bladder assembly positioned to engage a backside perimeter of the substrate.

48. (Canceled)

49. (New) An apparatus for electrochemically depositing a metal onto a semiconductor substrate, comprising:

a container having a fluid inlet, a fluid outlet, and an open portion, the container being configured to contain an electrochemical plating solution therein;

a substrate holder assembly configured to electrically contact a substrate plating surface and support the plating surface in fluid communication with the electrochemical plating solution via the open portion;

an anode in fluid communication with the electrochemical plating solution;

a porous fluid flow adjustment member positioned across the container between the anode and the open portion; and

an egress gap of between about 1mm and about 30mm between an outer surface of the substrate holder assembly and an inner surface of the container, wherein the egress gap is between about 2mm and about 6mm.

50. (New) An apparatus for electrochemically depositing a metal onto a semiconductor substrate, comprising:

a container having a fluid inlet, a fluid outlet, and an open portion, the container being configured to contain an electrochemical plating solution therein;

a substrate holder assembly configured to electrically contact a substrate plating surface and support the plating surface in fluid communication with the electrochemical plating solution via the open portion;

an anode in fluid communication with the electrochemical plating solution;

a porous fluid flow adjustment member positioned across the container between the anode and the open portion; and

at least one auxiliary electrode positioned in fluid communication with the electrochemical plating solution.

51. (New) The apparatus of claim 50, wherein the at least one auxiliary electrode comprises at least one electrode member positioned below the substrate plating

surface, the at least one auxiliary electrode being in electrical communication with a source of electrical power.

52.-89. (Canceled)